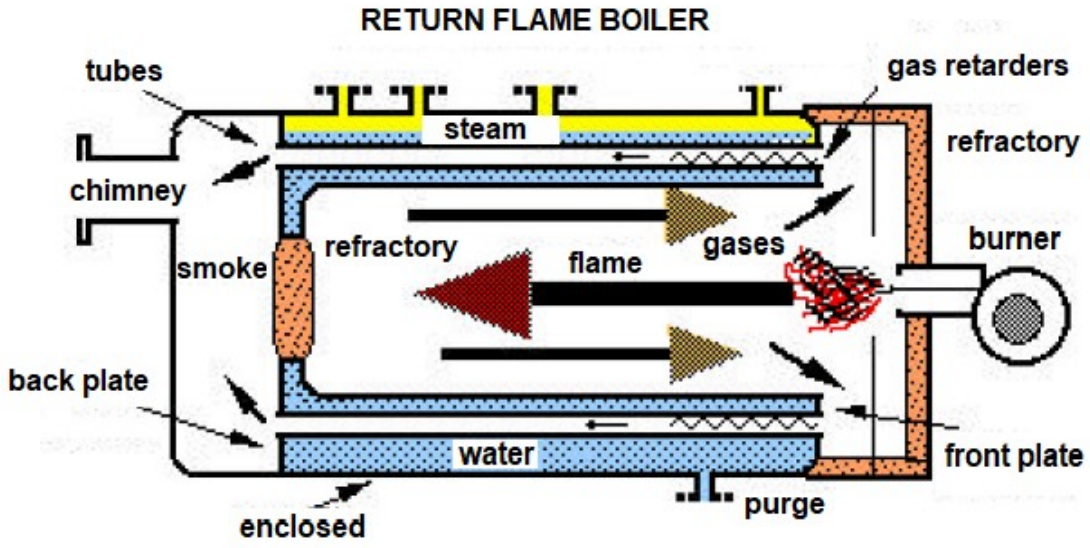
CHAPTER 4: Components of a Boiler Part 1

Structure (body and tubes)

Boilers are composed of a metal structure, usually cylindrical, made of iron. This pressure vessel is partially filled with water (or a mixture of water and steam) and partially with steam (steam chamber).

Another part is generally made up of tubes (in which the water-steam or combustion gases circulate), depending on the type of boiler (water-tube or fire-tube).

In fire-tube boilers, the body or casing has "plates" at each end that support the combustion chamber (which can be smooth or corrugated as needed) and the "flue tubes" (which are either "mandrelled" or “mandrel and welded” to the plates, depending on the standards).



Mandrilling:

This is the expansion of the tube over the hole in the plate. It is done with a tool that has a series of steel rollers that open as they rotate due to the action of the central shaft, stretching the tube and increasing its diameter to a desired value of material deformation once the diameters are equalized.

Depending on the material, this deformation will be: steel (iron) from 5% to 7%, stainless steel from 4% to 5%, and copper and its nickel alloys from 8% to 10%. See chapter later.

Then, in some cases, they may be "flared" (this is done on the protruding part of the tube above the plate to prevent the end of the tube from being "burned" by the hot gases, by "flaring" or "relieving" the protruding edge against the plate) or "belled" (a bell-shaped expansion of the protruding end of the tube above the plate to prevent displacement when necessary or to improve the circulation of gases or water).

In fire-tube boilers, or in water-tube boilers, this is done with a mandrel or percussion cone. A combination of mandrelling (expansion of the tube into the hole in the plate) and sealing with electric welding (followed by a second mandrelling to "relieve stress").

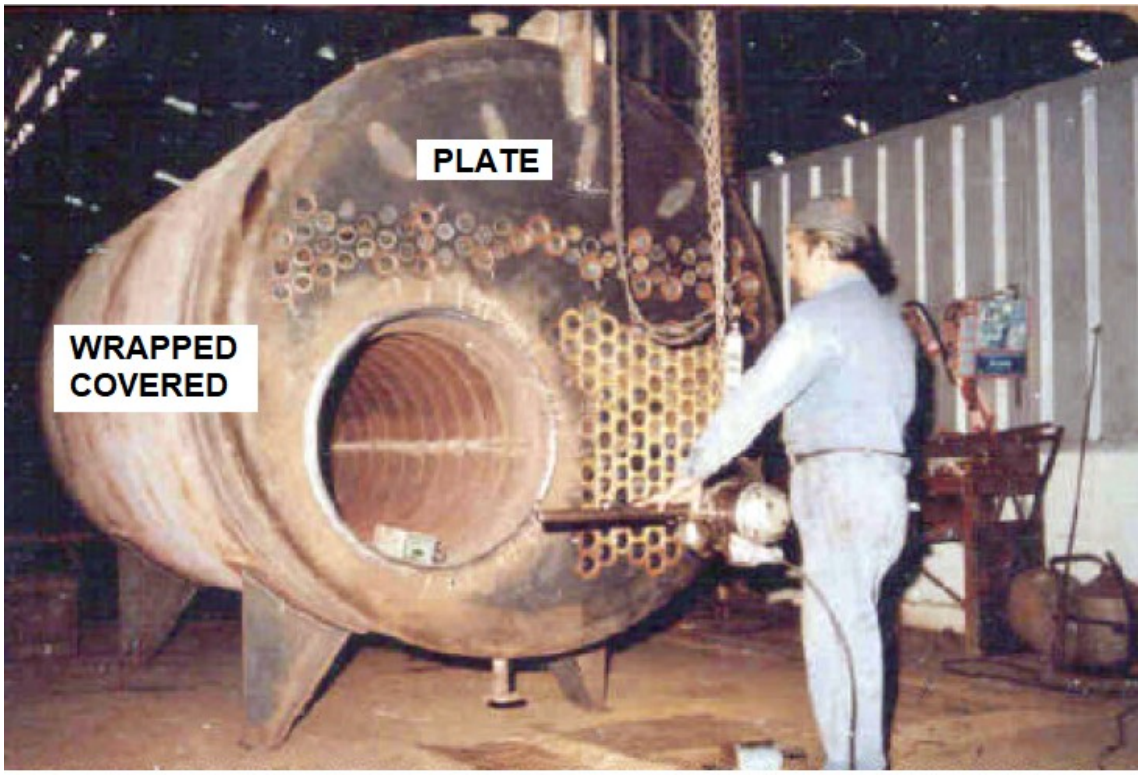
However, in water-tube boilers, the tubes are generally only mandrelled (except in the headers) in the domes. Typically, the tube is mandrel to a complete seal and a holding tension, with a "flaring" effect not only to prevent its "extraction" due to the stresses it withstands, but also to improve the circulation of the water entering the tube (a "funnel" effect, which reduces the "pressure loss" of the water as it enters the tube).

MANDRILLING TUBES IN A WATER-TUBE BOILER DOME

Today, in almost all fire-tube boilers, the tubes are mandrel-grooved and welded to the plate.

The tubes are welded to achieve a good seal, but some tubes are welded deeper than others, as these will be the "stay" or support tubes between the plates (meaning they withstand the pressure exerted on the flat plates).

Although the tubes are welded, they must first be mandrel-grooved and then, after welding, mandrel-grooved again to loosen the tension generated by the welding process and retighten the mandrel that loosened during welding (the tube that has reached a certain temperature). The mandrel acts as the "anchor" of the tube to the plate, and the weld provides the seal, especially in the case of the "stay" tubes.

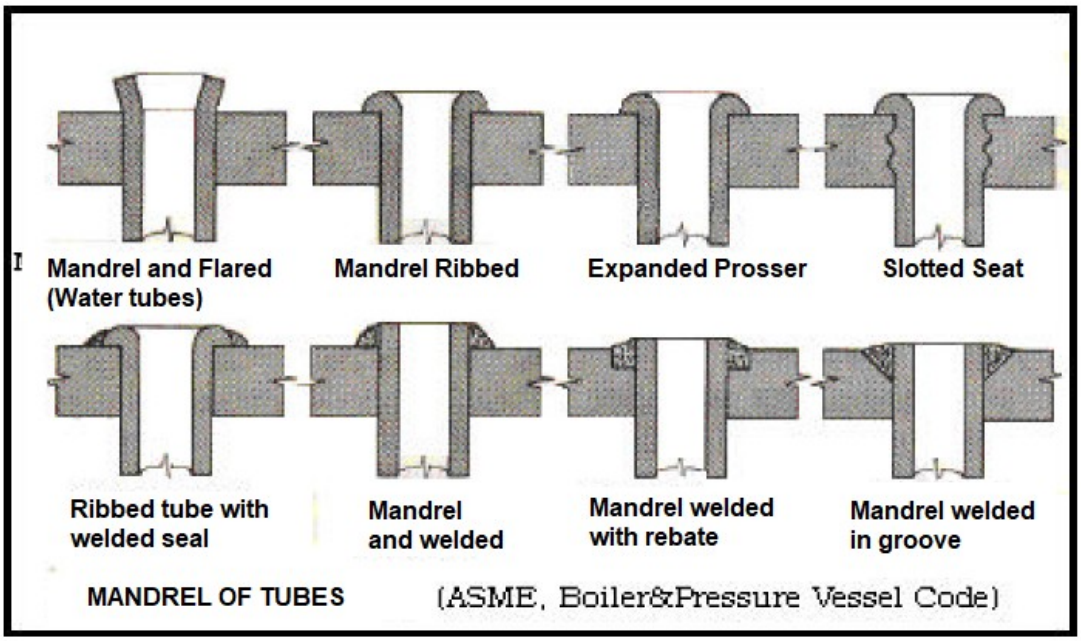


MANDRILLING BORING TUBES TO PLATES (HOMO-TUBULAR BOILERS)

Although the tubes are welded, they must first be mandrel-grooved and then retightened after welding to relieve the tension generated by the welding process and to retighten the mandrel that has loosened during welding (the tube that has reached a certain temperature).

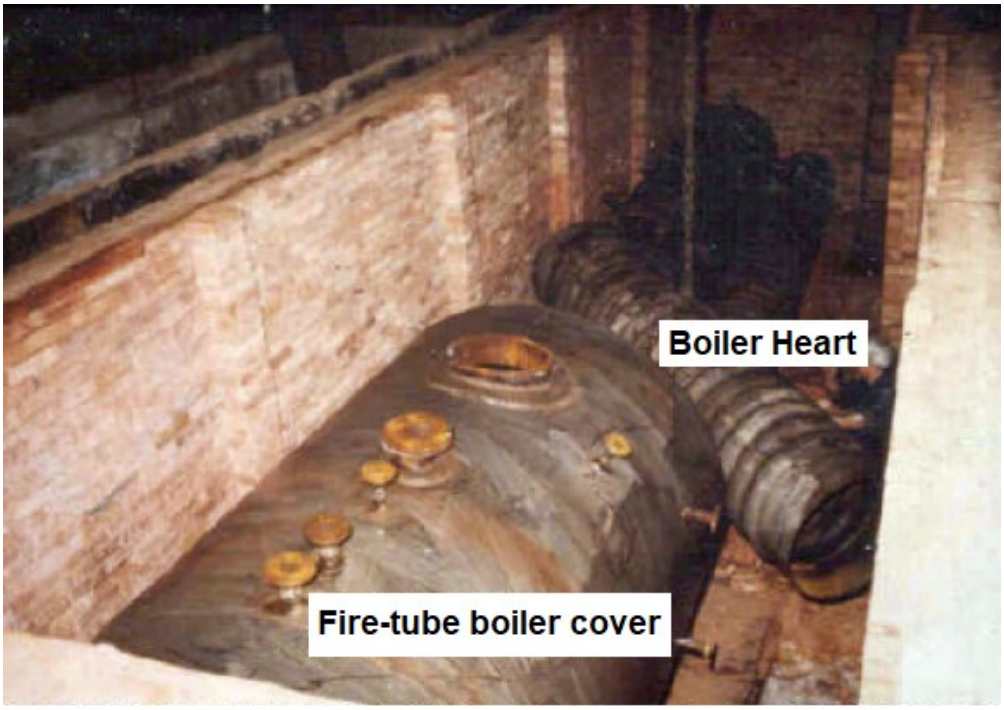
The mandrel acts as the "anchor" of the tube to the plate, and the weld provides the seal, particularly in the case of the "stay" tubes (reinforced tubes whose function is to withstand this great stress and that of the boiler's own pressure which exerts a stress on the plates).

The mandrel is what anchors the tube to the plate, and the weld provides the seal. The welding also acts as an anchor (if the tubes were not mandrel-grooved, there will most likely be problems over time, from losses in the welds due to insufficient "anchoring" or corrosion in the gap between the plate and the tube).



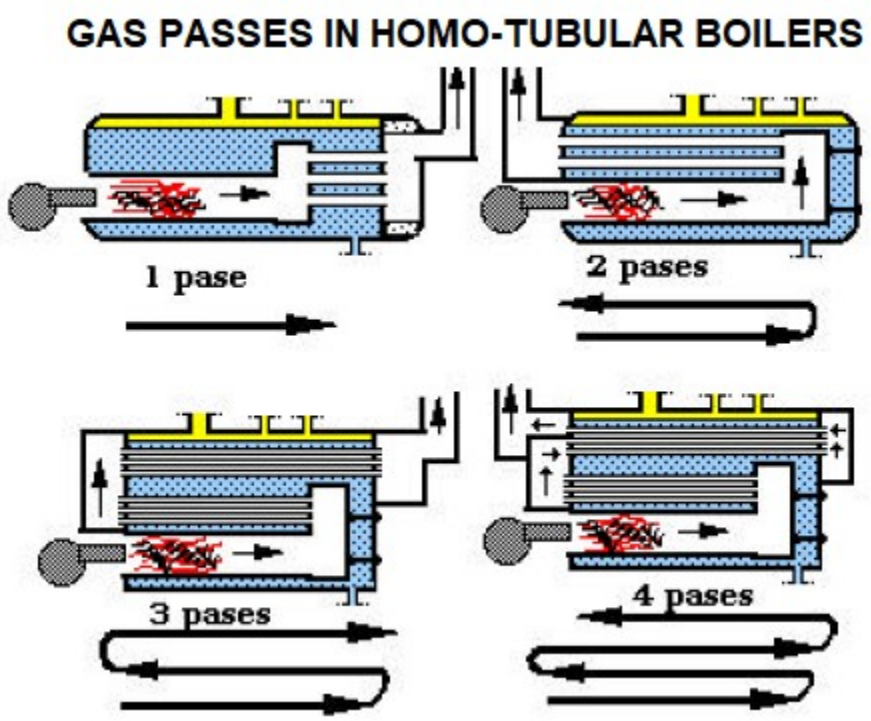
Since the pressure vessel of a boiler is constructed by welding, even though the material is generally low-carbon (and very high-purity) steel, it retains stresses in the welded area.

Therefore, it undergoes a "stress-relief" heat treatment. This treatment has a cost, but it is generally worthwhile, as it reduces the risk of failures due to cracks in the welded areas during the boiler's lifespan (which in Uruguay is generally more than 30 years).

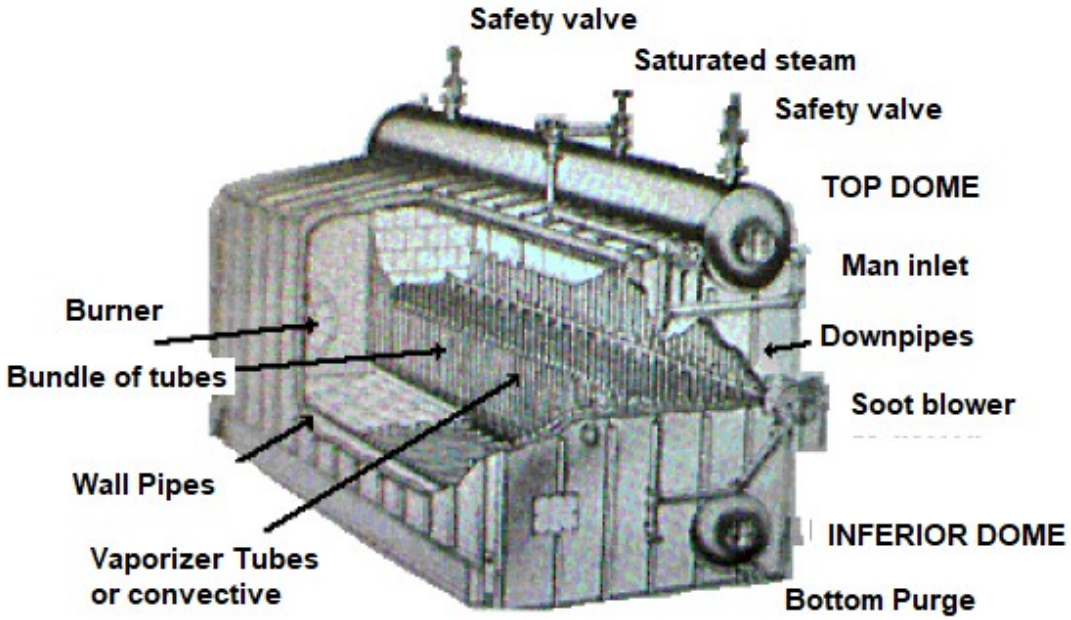


HEAT TREATMENT FURNACE FOR STRESS RELIEF

Fire-tube boilers are often classified by the number of "passes" (or changes in the direction of gas flow). The "first pass" is the furnace tube (when present), and the "second pass" is the "first tube pass." Generally, boilers do not exceed four passes in total, with three-pass boilers being the most common, although smaller boilers are usually two-pass.



Water-tube boilers are made up of "domes" and/or collectors that will be joined by tubes through which the water circulates (which will be "mandrel-shaped" and if necessary "bell-shaped" or welded depending on whether it is a dome or a collector).



The metals that form these pressure structures are special (although they are generally not high-carbon steels, they

are manufactured according to very strict standards – and should not be replaced by common materials, since they must withstand very significant stresses at generally high temperatures, tensions due to the aforementioned effects, and all types of exposure to a corrosive environment, whether from gases or water/steam).

The welds are also done with special electrodes, following specific standards (procedures), and by qualified welders.

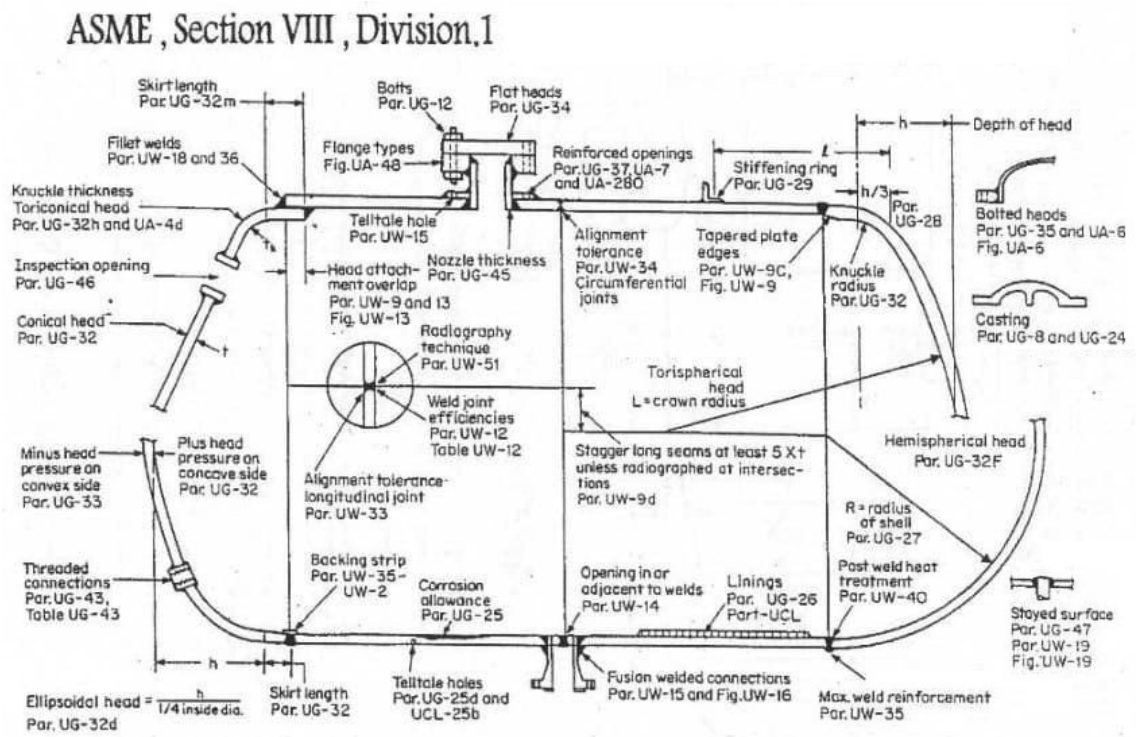
The "shells" and their "plates" in fire-tube boilers, and the "domes" and "collectors" in water-tube boilers, once manufactured, undergo annealing to relieve stress and are subjected to X-rays or other tests to inspect the welds or areas of risk (cracks, inclusions, etc.).

Once its construction is complete**, hydraulic tests** are performed to observe the behavior of the structure and the connection of the tubes to the plates, domes and collectors.

Note in the following figure that the construction standards for pressure vessels (represented in a simplified form by a specialist), especially boilers (vessels subjected to variable stress and temperatures), adhere to very strict "construction standards," as human life and the integrity of the environment in which a boiler is installed are at stake.

The joining of the "plates" to the "shells," and the welding of the "shell" upon itself (to close its circumference), are particularly "delicate" areas, as they are subjected to pressure stresses and, in the case of boilers, to the variable stress of expansion and contraction of the cylindrical combustion chamber (where combustion occurs from "all to nothing," with 20% to 40% of the total combustion heat being transferred to the water) and the stress of expansion and contraction of the tubes (which transfer a large part of the heat, between 40% and 60%, from "all to nothing").

This stress is transferred to the "plates" and this can "fatigue" the joint until it weakens (causing one of the most serious accidents, which is the "explosion" of the pressure body).

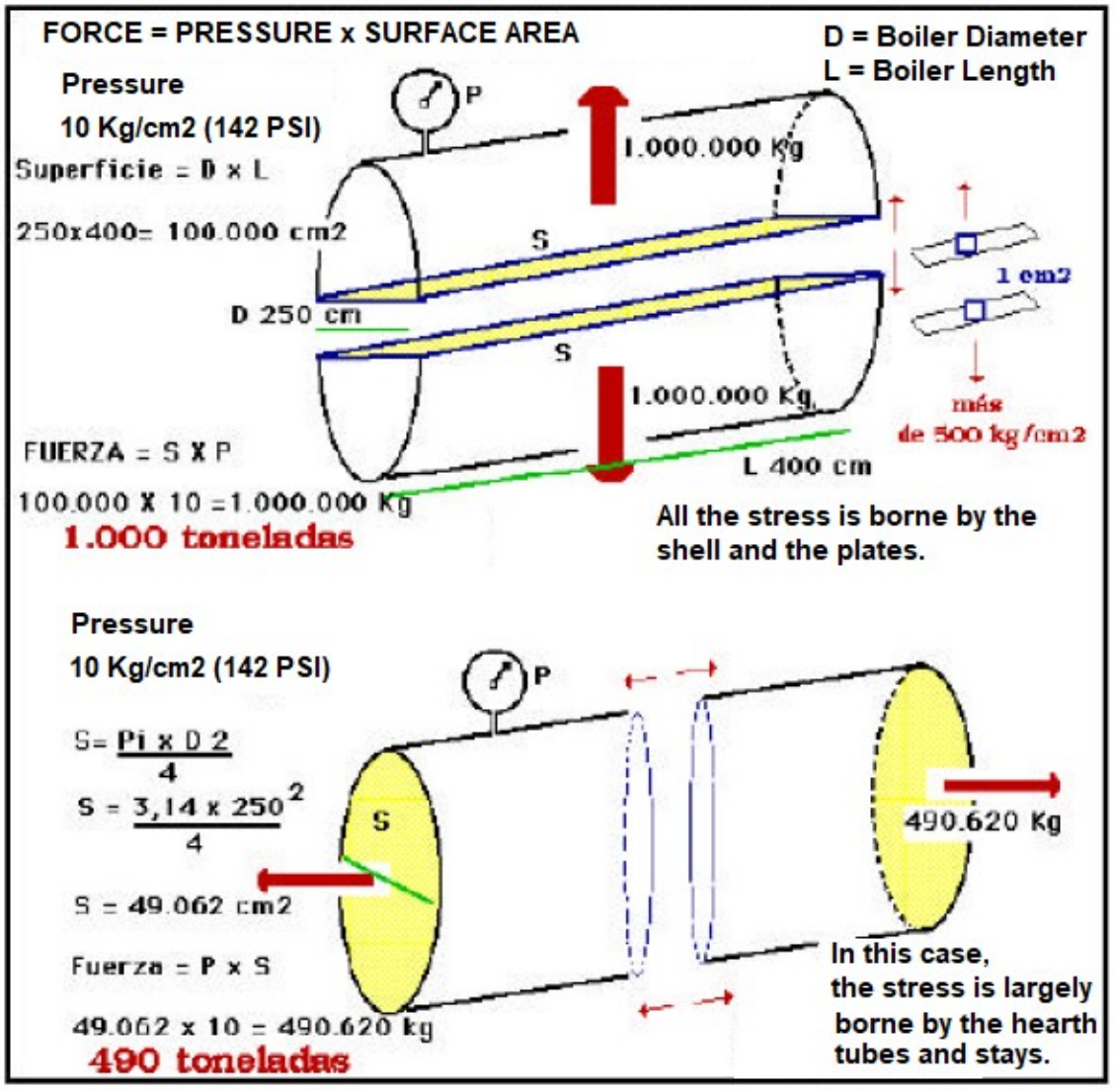

ASME , Section VIII , Division.1
Skirt length Par. UG-32m
Bolts Par. UG-12
Flat heads Par. UG-34
Fillet welds Par. UW-18 and 36
Flange types Fig. UA-48
Reinforced openings Par. UG-37, UA-7 and UA-280
Stiffening ring Par. UG-29
h
Depth of head
h/3
Par. UG-28
Bolted heads Par. UG-35 and UA-6 Fig. UA-6
Knuckle thickness Toriconical head Par. UG-32h and UA-4d
Telltale hole Par. UW-15
Alignment tolerance Par. UW-34 Circumferential joints
Tapered plate edges Par. UW-9C, Fig. UW-9
Knuckle radius Par. UG-32
Inspection opening Par. UG-46
Head attachment overlap Par. UW-9 and 13 Fig. UW-13
Nozzle thickness Par. UG-45
Casting Par. UG-8 and UG-24
Conical head Par. UG-32
Radiography technique Par. UW-51
Torispherical head L = crown radius
Weld joint efficiencies Par. UW-12 Table UW-12
Minus head pressure on convex side Par. UG-33
Plus head pressure on concave side Par. UG-32
Alignment tolerance longitudinal joint Par. UW-33
Stagger long seams at least 5 X t unless radiographed at intersections Par. UW-9d
Hemispherical head Par. UG-32F
R = radius of shell Par. UG-27
Threaded connections Par. UG-43, Table UG-43
Backing strip Par. UW-35-UW-2
Corrosion allowance Par. UG-25
Opening in or adjacent to welds Par. UW-14
Linings Par. UG-26 Part-UCL
Post weld heat treatment Par. UW-40
Stayed surface Par. UG-47 Par. UW-19 Fig. UW-19
h
Ellipsoidal head = h / 1/4 inside dia. Par. UG-32d
Skirt length Par. UG-32
Telltale holes Par. UG-25d and UCL-25b
Fusion welded connections Par. UW-15 and Fig. UW-16
Max. weld reinforcement Par. UW-35

Hydraulic testing:

This involves subjecting the boiler body to a pressurized water pressure at ambient temperature, after completely removing the air from the interior. It is an internal stress within the material's elastic limit (for a specific time) to observe any leaks or deformation.

The test pressure varies according to standards: generally, for medium-pressure boilers, it is set at one and a half times the design pressure.

Hydraulic testing must be carried out by qualified personnel (professionals or qualified individuals). Exceeding the pressure, time, or proper procedure risks damaging the boiler.


FORCE = PRESSURE x SURFACE AREA
D = Boiler Diameter
L = Boiler Length
Pressure
10 Kg/cm2 (142 PSI)
Superficie = D x L
250x400= 100.000 cm2
P
1.000.000 Kg
S
D 250 cm
1 cm2
más de 500 kg/cm2
1.000.000 Kg
L 400 cm
FUERZA = S X P
100.000 X 10 =1.000.000 Kg
1.000 toneladas
All the stress is borne by the shell and the plates.
Pressure
10 Kg/cm2 (142 PSI)
S= Pi x D 2 / 4
S = 3,14 x 250 2 / 4
S = 49.062 cm2
Fuerza = P x S
49.062 x 10 = 490.620 kg
490 toneladas
490.620 Kg
In this case, the stress is largely borne by the hearth tubes and stays.

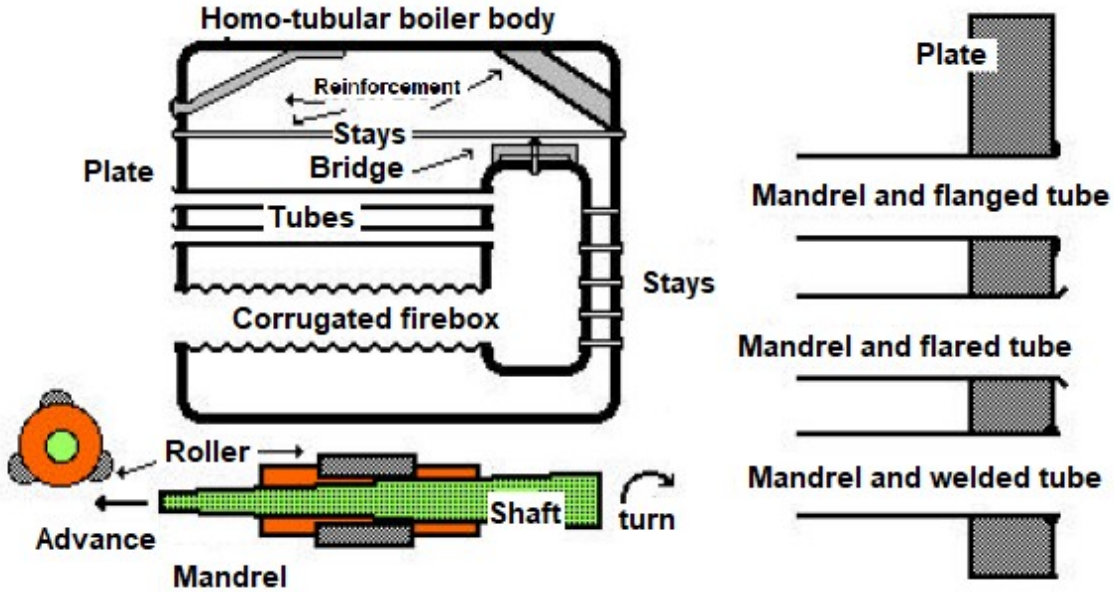
Fire-tube boilers may also have stays (internal braces) or other elements (braces) and stay tubes (tubes that may be thicker, welded or mandrel-grooved, flanged, or flared more firmly to the plates).

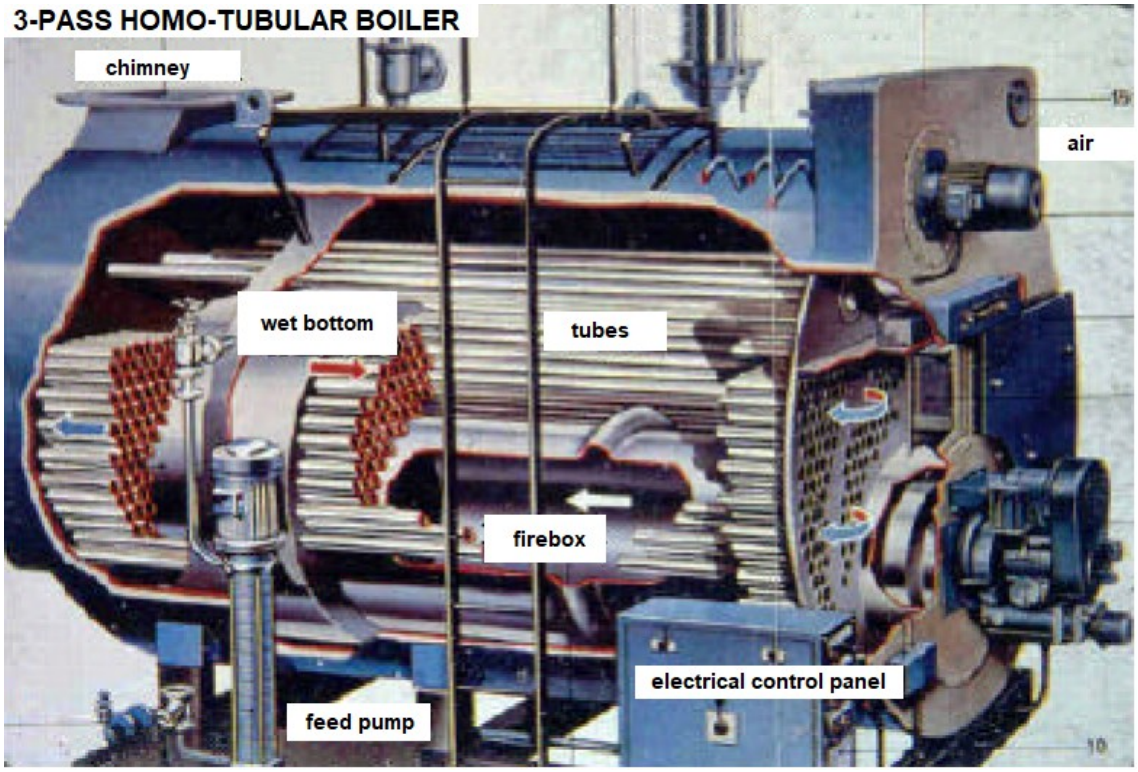
These elements keep the plates or flat areas correctly aligned (without deformation) when subjected to the high stresses caused by pressure.

For a simple boiler operating at 7 kg/cm² (99.5 PSI) gauge pressure, with plate diameters of Ø1400 mm (55.1 in), the force the plate must withstand will be the product of the surface area and the pressure in compatible units: 108 tons (from which the stress on the surface area occupied by the combustion chamber and the tubes on the plate must be subtracted).

These components must be treated with great care, as their good condition is essential (do not modify them, protect them from any type of corrosion, inspect them periodically, etc.).

The stress on the casing is even greater.





The cylindrical combustion chamber of fire-tube boilers can be "corrugated" (with cylindrical shapes of varying dimensions and profiles, which allows the chamber to better withstand pressure and partially absorb the significant expansion stress caused by the high temperature of the flame inside)

or "smooth" (a simple cylinder, which may have cylindrical supports, such as rings, on the water side, i.e., the cooled side).

Smooth cylindrical combustion chambers are limited to small-capacity boilers, since the problem of expansion is not taken into account, although in some cases a single "ruffle" or "expansion joint" is added for this purpose.

The most common "corrugated" system is the FOX system (since it is the simplest to manufacture). Typically, once the firebox has been rolled with a single longitudinal weld, it is then subjected to a type of lathe with embossing wheels that create the "crisp" shape, and torches that heat the material in the area to be deformed.

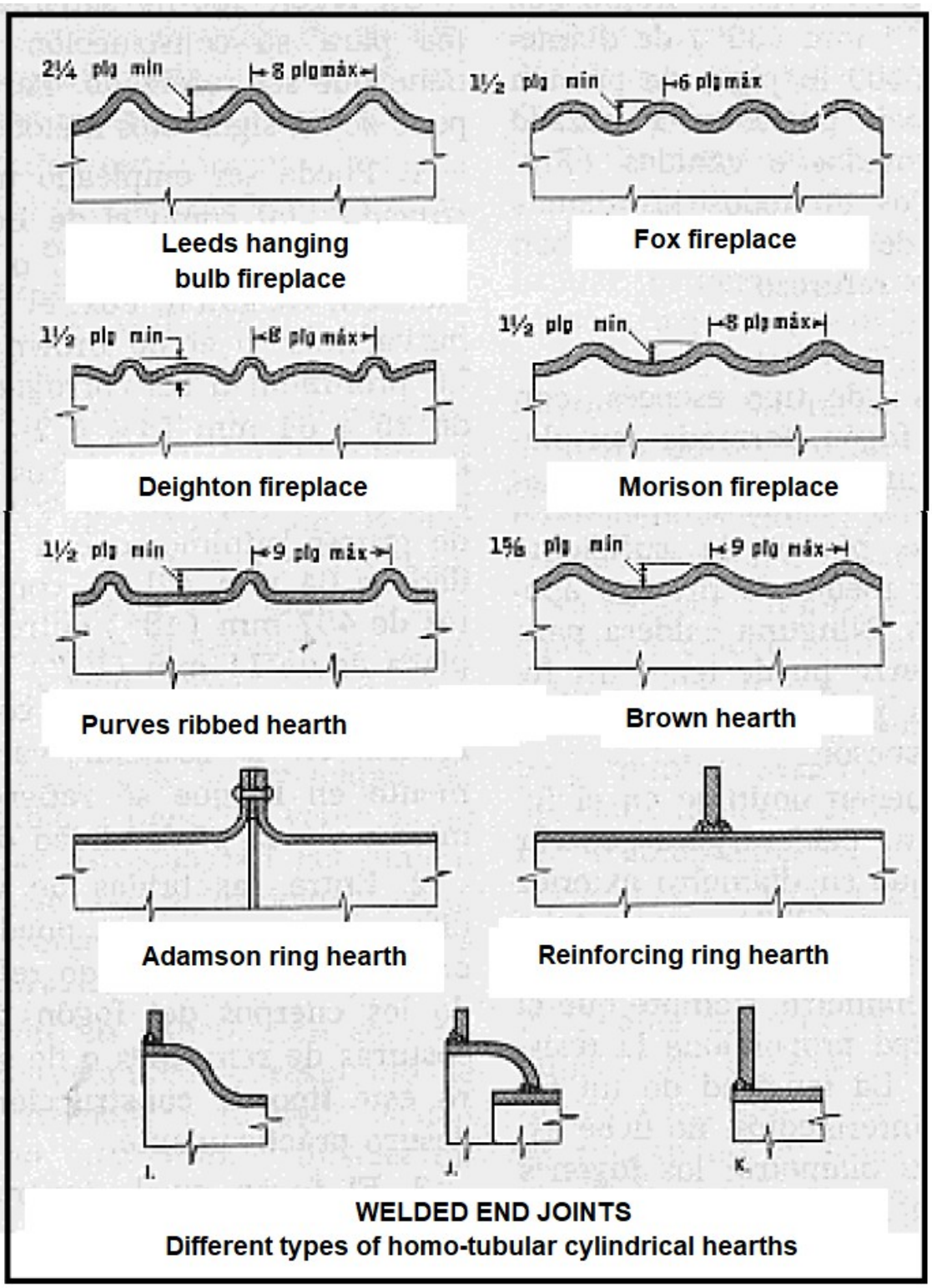
CONSTRUCTION OF A CYLINDRICAL HOMO-TUBULAR BOILER

Another way to make a "corrugated" firebox is to create it in two halves using a press, after preheating the material to be deformed, and then welding the two halves together.

The cylindrical combustion chamber of fire-tube boilers serves the dual purpose of enabling combustion and operating at high temperatures. Therefore, adequate water cooling is essential. This cooling circulation can be affected not only by a low boiler level but also by various water surface conditions (chemical limits and contaminants), as well as the combustion percentage and flame configuration.

However, it also plays a crucial role in creating a water "pump" within the fire-tube body. This not only cools the metal of the combustion tube but also "washes" the fire-tubes, preventing sludge buildup.

Boilers without combustion tubes experience problems if the combustion process produces sludge, which is not easily removed through the purge system.


2¼ plg min
8 plg máx
Leeds hanging bulb fireplace
1½ plg min
6 plg máx
Fox fireplace
1½ plg min
8 plg máx
Deighton fireplace
1½ plg min
8 plg máx
Morison fireplace
1½ plg min
9 plg máx
Purves ribbed hearth
1⅝ plg min
9 plg máx
Brown hearth
Adamson ring hearth
Reinforcing ring hearth
I.
J.
K.
WELDED END JOINTS
Different types of homo-tubular cylindrical hearths

The expansion of the cylindrical combustion chamber in a fire-tube boiler causes stress between the plates (unless the combustion chamber is "floating," as in some "return flame" boilers).

The tubes connecting the plates and the shell withstand this stress, since the heating of the combustion chamber at certain times causes greater expansion than the tube passages.

Therefore, there are reinforced tubes, "stays," whose function is to withstand this significant expansion stress and the pressure exerted by the boiler's steam itself, which acts on the plates. These plates are flat, and therefore their shape is not ideally suited to withstand stress that could distort them.

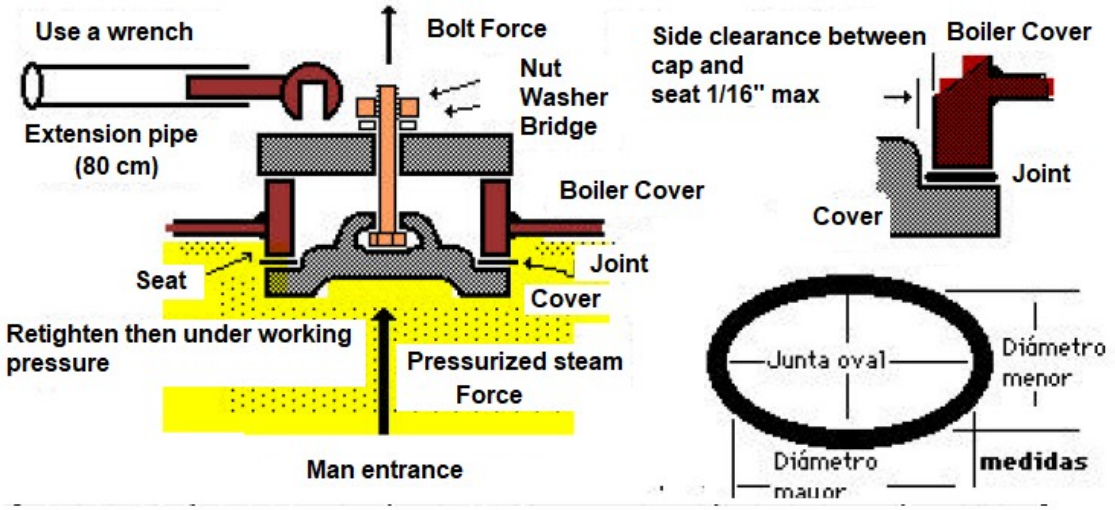
Today, tubes are mandrel-grooved and welded; previously, they were only mandrel-grooved and upset (that is, their ends were flattened or flared for two reasons: to better withstand stress and to prevent the protruding ends of the tubes from burning during the first pass, where the temperature reaches 900°C (1652°F) at the furnace outlet).

Stay tubes, which used to be thicker and sometimes secured with nuts, are now generally welded with a stronger weld, a deeper weld, than tubes that only need to maintain a watertight seal with the weld alone.

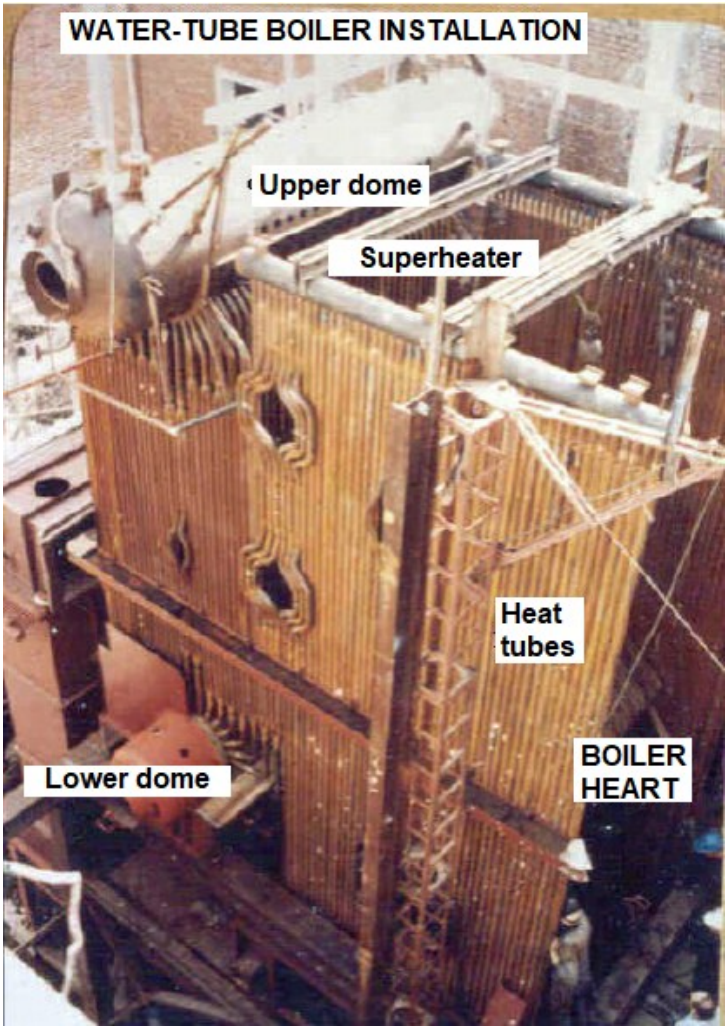
When a boiler is scaled, the combustion chambers, plates, and tubes experience reduced cooling, leading to increased expansion that tends to crack the mandrel welds, loosen the mandrel tubes, crack the tubes and plates between tube holes, or even cause cracking at the combustion chamber ends, or, in some cases, fatigue and collapse.

This same problem of abnormal expansion occurs when boilers are heated too quickly from a cold state.

The manholes, also known as "head" or "hand" access points, allow us to inspect the inside of the boiler for cleaning and general observation.

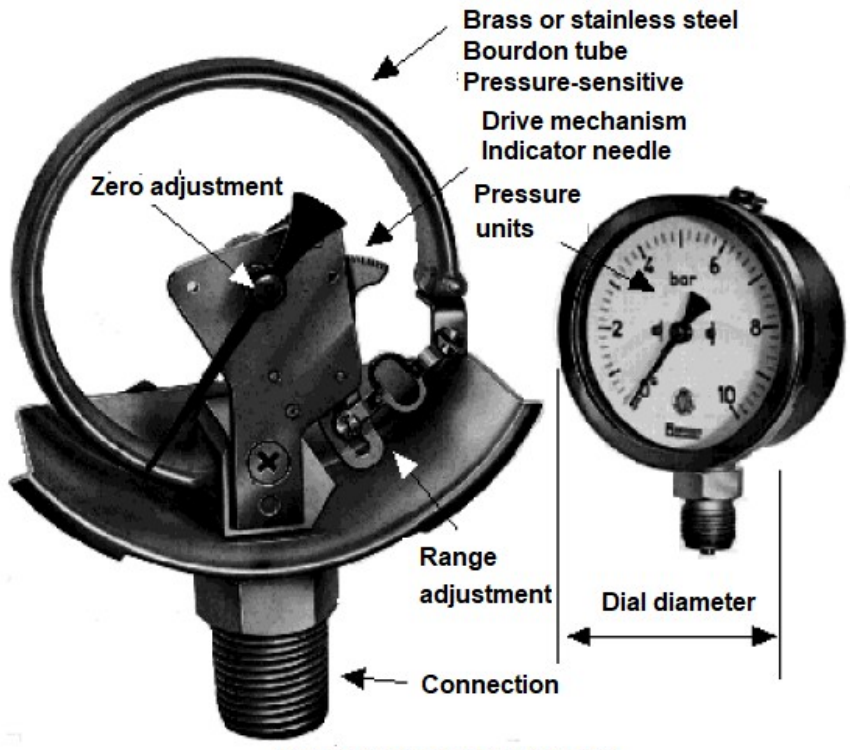


To this "body" that forms the boiler, we must apply a series of accessories for its correct operation and safety, which we will discuss below.



The pressure gauge

This component allows us to monitor the internal pressure of the water and steam (working pressure). It is crucial that its reading is accurate, as the stress the boiler endures is measured based on pressure, and the quality of the steam is controlled by pressure (as we saw, the saturation temperature of water vapor corresponds to a specific pressure). We can say that it is the most precise instrument required in the boiler.



BOILER PRESSURE GAUGE

A needle indicates the pressure in established units (kg/cm², bar, PSI, lb/in², etc.). The reading can be absolute or relative, but it is generally relative: "gauge." This is verified by exposing the connection to air—or by cooling the boiler with the atmospheric valve open; the pressure will read zero, as it is gauge pressure.

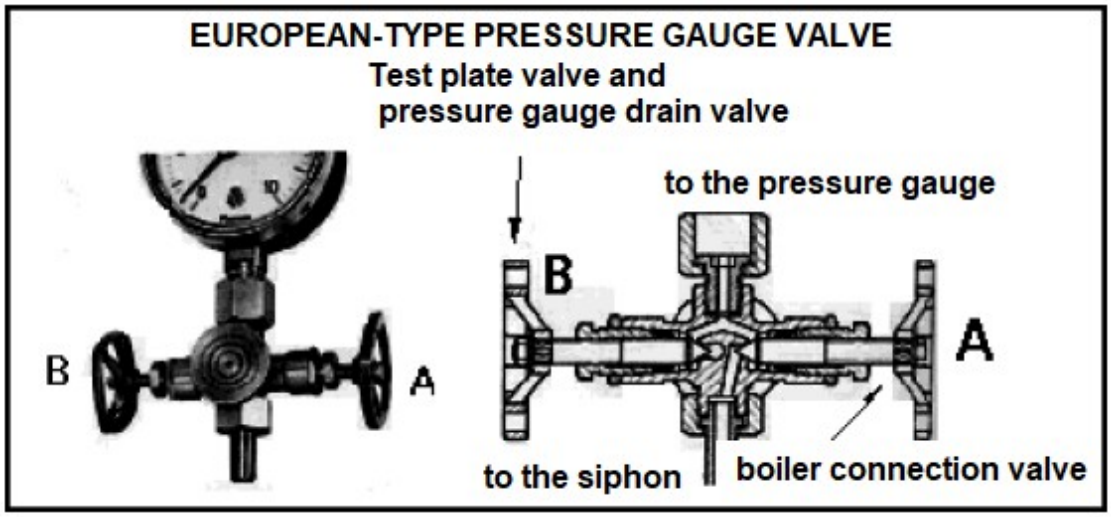
The needle is generally moved by a bent metal tube (bronze or stainless steel) called a "Bourdon tube," which, when subjected to pressure, tends to straighten, moving a mechanism of levers and gears that rotate the needle.

The pressure gauge scale should be 11/2 times (more than five) the "ringing" pressure (that is, the maximum design working pressure for the last safety valve to open), and its dial should be large enough to be seen from anywhere in the boiler room (and equally well illuminated).

The pressure gauge will be connected to the steam chamber with a 3-way valve for eventual purging or the connection of a master pressure gauge or changing the pressure gauge (there are generally two types of valves, American type or European type; the American type has a 3-way valve, the European type has 2 valves that perform the same function), in addition to a system that isolates it from the direct action of the steam (heat and corrosive gases), which may be: a "pig's tail", a 'U' tube or chamber.

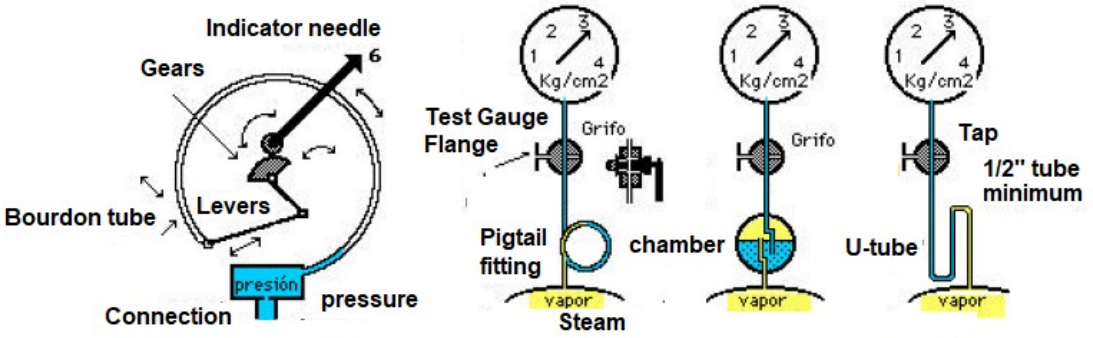
The 3-way valve is special; the pressure gauge and the outlet to the standard (plate) can never be isolated, so that the pressure gauge remains with hydraulic pressure, in a false pressure, since the internal pressure will go through the hole in the plate, or steam will escape through the plate; The handle will move downwards along the pipe (minimum 1/2" pipe) when in normal operation. This way, it will never be accidentally disconnected and the internal pressure will be ignored.

If the connection to the boiler is closed, the pressure will drop to zero due to the discharge through the plate, or the master pressure gauge can be used while the service pressure gauge is being replaced.



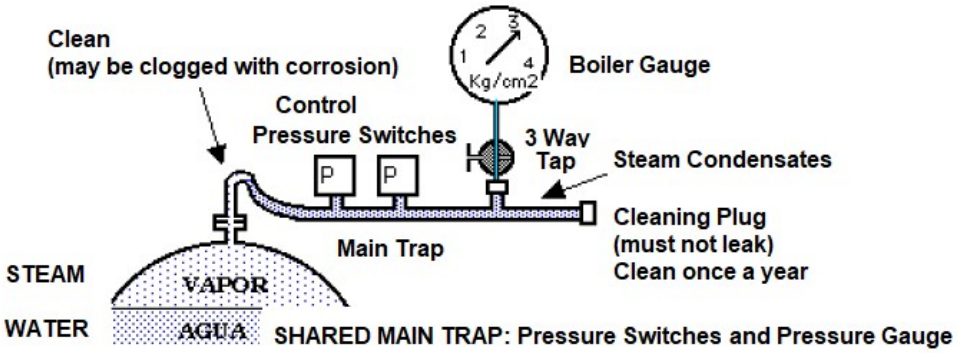
In European-type taps, the pressure gauge and the plate of the test master pressure gauge are already separated by a valve that closes the connection to the plate. This makes it possible to become isolated from the boiler accidentally if someone closes the valve connecting to the siphon.

Pay close attention to the operation of these valves to avoid an error that simulates a false pressure reading (tap closed to the siphon connection). If the pressure gauge is closed, the plate also closes, so the pressure gauge cannot be changed while the master gauge is in service.



Manometer mechanism

Manometer connection instructions



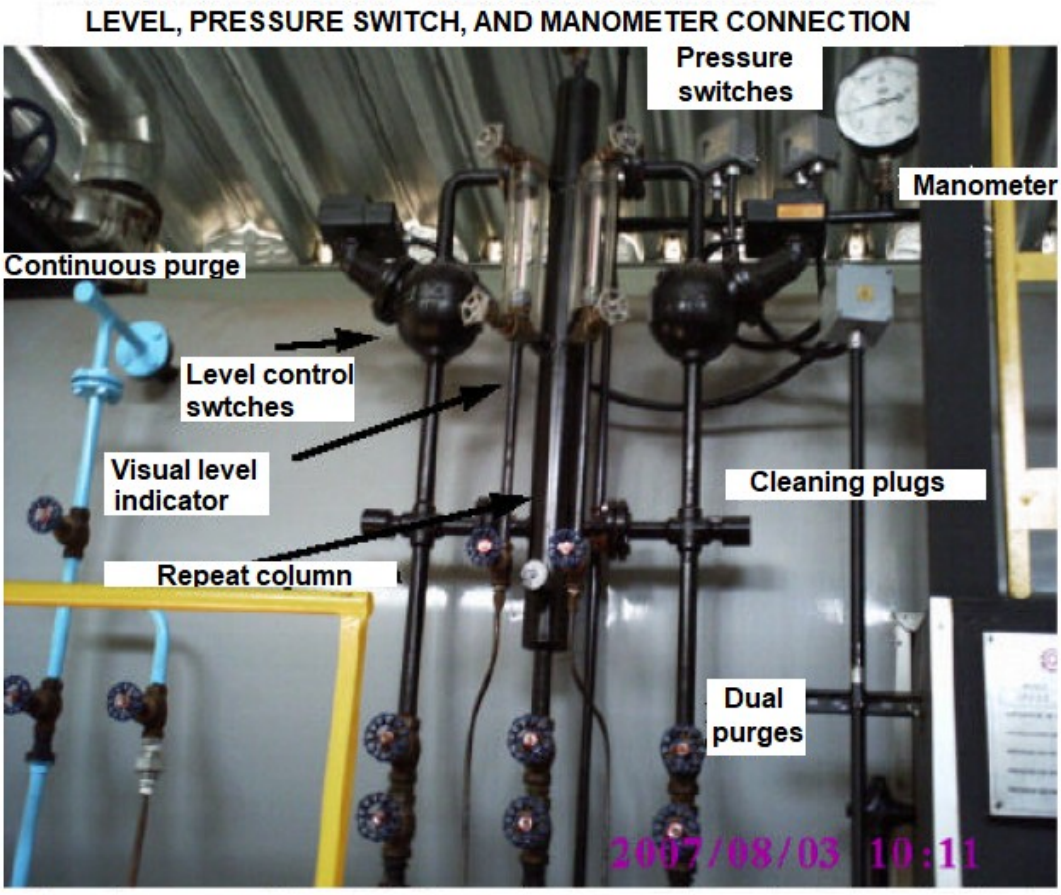
An annual functional check of the pressure gauge ("calibration" or comparison with a standard pressure gauge) must be carried out.

Several faults can occur between the boiler control elements and the connections to the steam chamber (in the case of steam boilers).

These range from human error, such as **installing shut-off valves between the siphons** and the boiler (which should never be done).

But the most common issue is a **leak in the end cleaning plug** of a multi-pipe siphon (for both the pressure gauge and the control pressure switches). This causes corrosion in the siphon pipe, which tends to become clogged (as do the connections to the pressure gauge or pressure switches).

Another fault is that with a European-style tap, the connection to the boiler can be accidentally closed while there is hydraulic pressure inside, resulting in a false reading. This false reading, when used as a reference, can lead to errors.



This system does not include a test valve (because it has two visual level indicators).

The other issue arises when purges are installed at the end of a common siphon and the siphon is repeatedly purged. This affects both the pressure gauge and the pressure switches because they come into contact with the steam instead of the already cooled, condensed water in the siphon (this was an old practice used in boilers due to poor chemical treatments that tended to clog the pressure gauge connection).

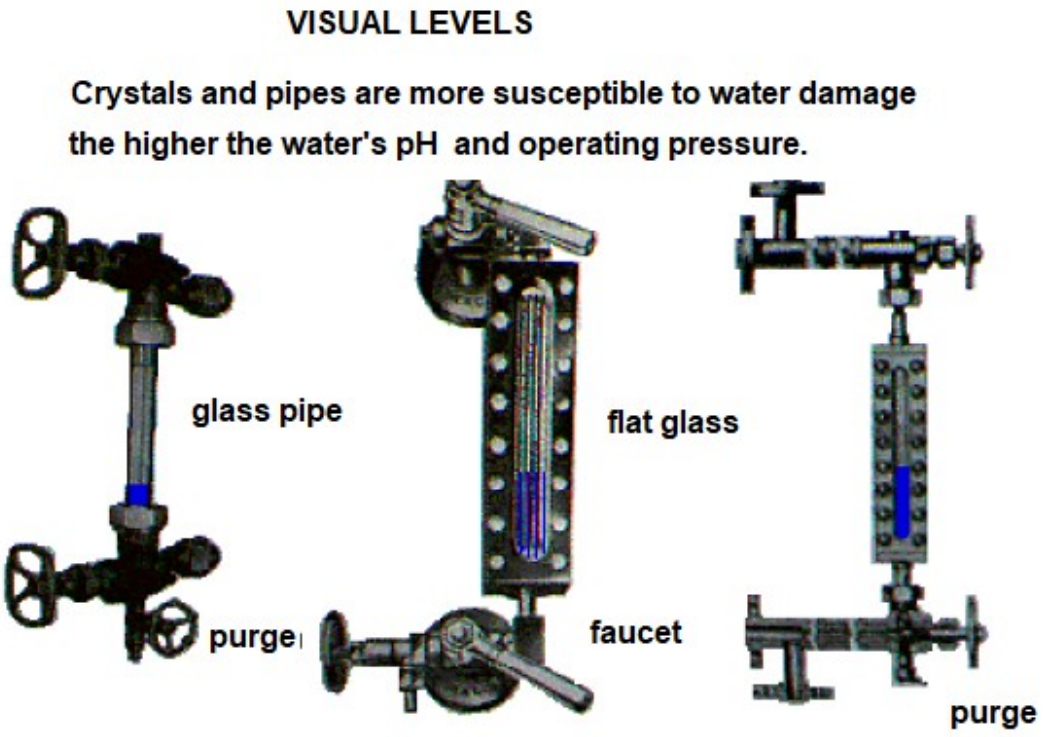
It's common for siphons, and especially the "common" siphon (shared by the pressure gauge and pressure switches), to become clogged due to corrosion. This is because the condensate in the siphon isn't chemically treated by the boiler; it's corrosive condensate, primarily due to the CO2 from the bicarbonates that decompose with heat.

When this common siphon becomes clogged, it can lead to the mistaken belief that the working pressure isn't being reached, even though the safety valves are tripping because the burner isn't shutting off at the correct pressure. (It's advisable to replace this siphon every few years, especially when using well water.)

Levels

The level is used to control and maintain the water level inside the boiler (this is achieved by adding or subtracting the amount of feedwater as it evaporates).

It is as important as, or even more important than, the pressure, because a boiler with insufficient water can overheat and even explode (when it runs out of water, the metal overheats and softens, the spontaneous evaporation of feedwater on the hot metal creates excessive stress, weakening the structure, etc.). Therefore, we will see three ways to control the water level, each one supporting the other two.



Sight glass:

This is a cylindrical glass tube or a "tube" with flat glass faces connected to a column that repeats the boiler's internal water level.

It is connected via valves to the column (allowing it to be closed for glass replacement and blowdown control) and to a blowdown valve (for draining every few hours of operation, for cleaning and monitoring the level return).

The connection to the column is made through small holes or holes with retaining balls, so that if the glass breaks, the loss of water and steam is not dangerous, allowing for the closure of the taps and repairs to be carried out. (An acrylic or tempered glass screen should be placed over the tube for protection when observing, in case the tube or glass shatters.)

Good lighting is essential, and a contrasting background can be used to visually highlight the separation between the water and the steam.

This can be achieved in several ways: on flat glass, by adding grooves to the glass itself; on glass tubes, by adding a colored stripe lengthwise to the back of the tube, or, on the outside of the tube, by adding a background screen with semi-horizontal grooves, generally in black and white.

The crystals and tubes are attacked by the free soda in the water; the higher the working pressure and the soda, the greater the attack on the "glass" of the tube or crystal, causing them to "burst." To prevent this in high-pressure boilers, a "mica" separation is placed between the crystal and the water.

Visual Level Check Valves: These are three valves mounted directly on the repeater column (or hydrometer column) so that we can determine if the water level is at the correct level (the top valve in the steam zone, the middle valve at the normal level, and the bottom valve at the minimum water level zone).

These valves must be tested daily to ensure they are functioning correctly. In case of a visual level failure, these valves provide an emergency visual check of the water level by opening them.

These valves have a discharge design (orifice and length) that allows for the differentiation between water and steam (this was achieved after testing with various valves), as this differentiation is crucial (to avoid confusion between steam only and water with flash steam).

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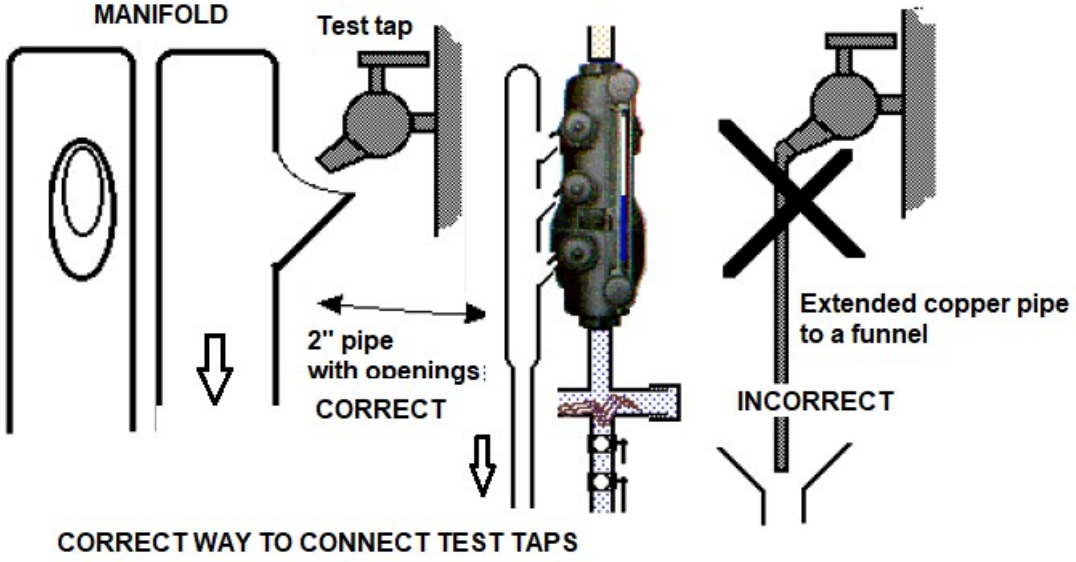


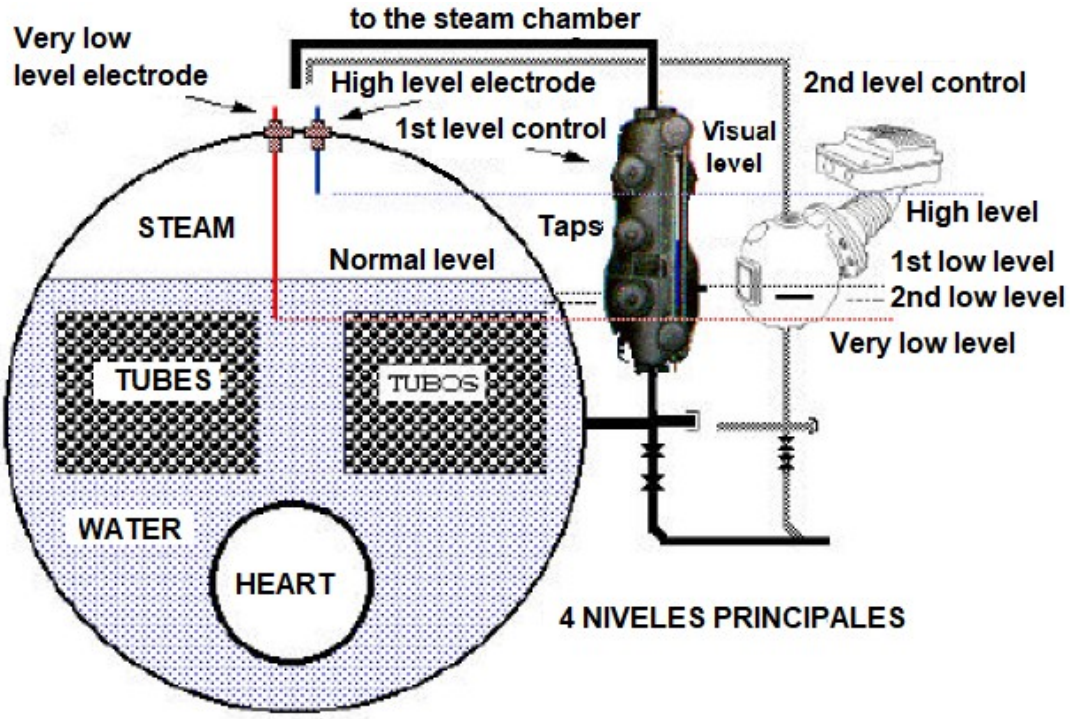
CORRECT WAY TO CONNECT TEST TAPS

Extension pipes should not be installed at the faucet discharge points, as they can obstruct the visual distinction between steam and water. Extension pipes can condense some of the steam, confusing the observer, since hot water also contains flash steam. See last diagram on the right.

If it is desired to collect the discharge, this is done in a pipe of sufficient diameter. Through openings or "cups" located in front of each faucet that discharges into the air, the discharged fluid enters through the opening or cup.

See last diagram on the left.

Never connect the drain manifold or pipe, which is open to the atmosphere, to the main boiler purge system, as bottom purge or level can cause a backflow of hot water and steam that can burn the boiler operator.



Automatic Level Control:

With visual level controls, we can only manually feed the water, and if the boiler runs out of water (low water level), we can manually shut off the burner or "fire" (with the boiler operator always present).

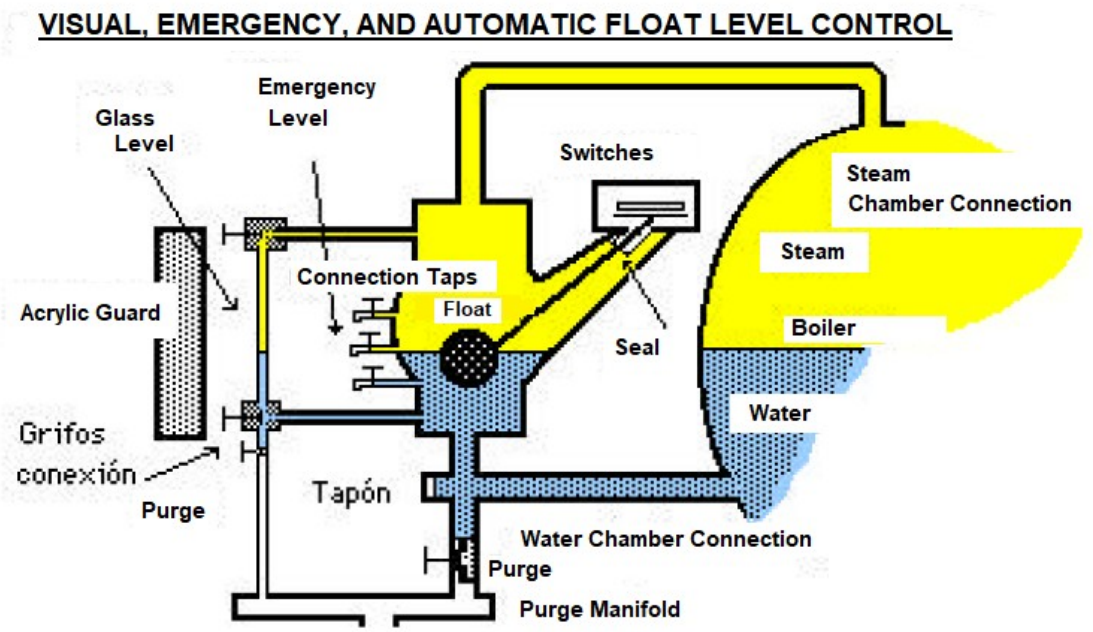
With automatic level controls We can operate the feed pump (turning it on/off or opening/closing the water supply to the feed pump), but fundamentally, in case of a low level: it will shut off the burner or "fires" (wood - cutting off and closing the combustion air and induced draft) and will sound a low water level alarm (alarm and indicator light).

Only when the normal level is restored can combustion be restarted. Shutting off combustion when the level is low is the most important thing.

These level controls can be mechanical (float), electro-electronic (based on **the electrical conductivity of water** by means of electrodes, which makes them vulnerable to problems related to water conductivity and fouling of the electrode's insulating elements by oils, sludge, or scale), or thermal (based on the difference in heat transfer between the steam and water zones in a tube exposed to both).

Mechanical float controls are the most common in low and medium pressure systems. In medium and high pressure systems, other types can be used, such as **differential pressure gauges** (which measure the pressure difference between a column of water at the normal level and the column of water at the actual boiler level; this difference is compared and translated into an electrical or pneumatic value, indicated on repeaters as a percentage of the level or visually by lights for the boiler operator to observe, and in commands for the boiler's feed system and minimum and maximum safety levels).

These level controls must be connected to the boiler body without connection valves (to avoid accidents due to forgetfulness), with purges for their total "purging" every few hours and their connections must have plugs for periodic cleanings (every 6 months or a year, as needed, since they can be blocked by the sludge accumulated inside).



The discharges from the purges to the collectors should have a "deviated" discharge with a curve (to avoid the impact, which causes wear due to erosion of the discharge) or place a stainless steel shock plate on the collector where the discharge impacts.

Modern boilers, regardless of the fuel, have at least two automatic level controls (in case the main one fails) so that they can always shut off the burner due to low water levels (and trigger the corresponding alarm; this second control blocks the burner until the operator re-enables it, after investigating the failure of the first level control and the cause of the low level).

This is due to the high vaporization rates achieved, which mean that a boiler can run out of water very quickly if there is a problem with the water supply (lack of water in the feed tank, a blocked feed pump—due to steam or mechanical

issues—failure of automatic feed controls, broken pipes, improper operation, etc.).

The level controls are very important; they must be purged every 4 hours by fully opening the purge valves (and in the case of automatic controls, ensuring that the burner shuts off if it is lit and that the low-level alarm sounds).

The level drains (purge) must be connected to a drain pipe (drain purge manifold) so that the drains can be fully opened to flush out the sludge. (If the drain were exposed to the air, it could not be fully opened due to the risk of burning, and the accumulated sludge, due to the small drain volume, would eventually block the control.)

As the boiler operates automatically with minimal constant supervision, two additional level controls may be present:

-One for **very low water level** (if the water level drops so low that the primary and secondary levels haven't shut off combustion, but remains above the heat transfer zones, in fire-tube boilers even above the upper tubes), **this very low level cuts power to the boiler's main control panel; shutting down everything, including the burner and feed pumps.**

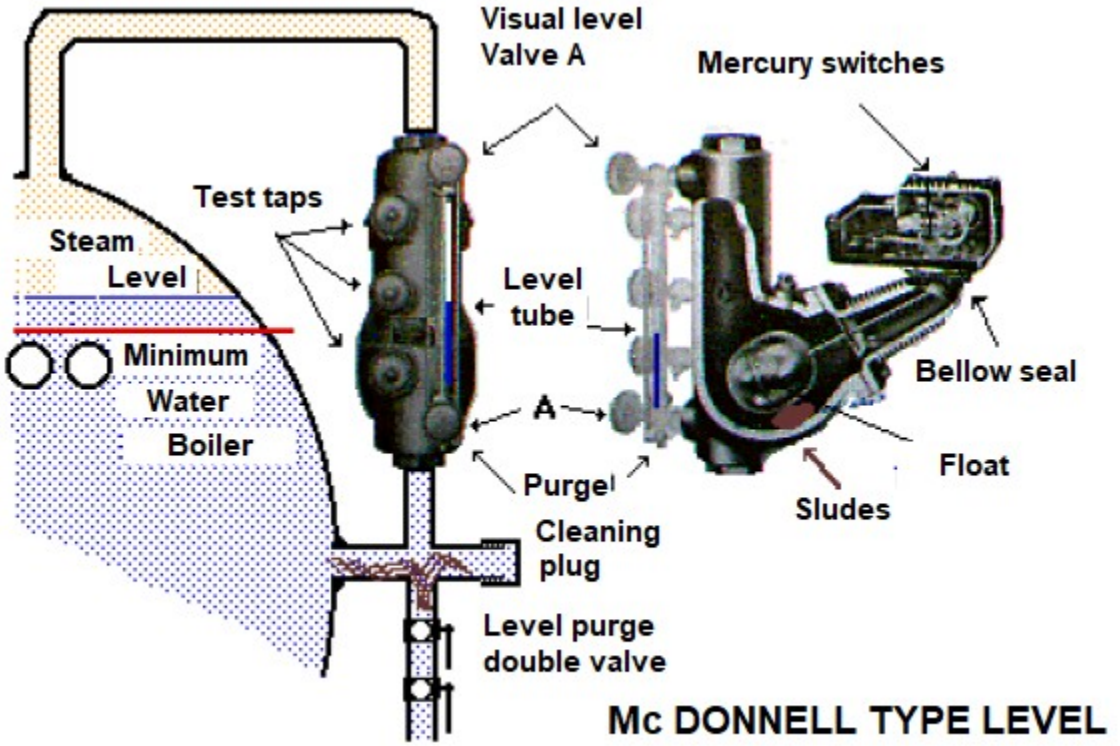
-The other additional level control may be for **very high water level** (this control cuts power to the control panel and, consequently, the feed pump, preventing the water level from rising further, thus avoiding water carryover from the boiler into the steam pipes; in other words, it protects the steam system, not the boiler itself).

Both levels have audible and visual alarms with manual reset so the operator can understand what is happening.

Generally, both controls operate using conductive electrodes connected to the boiler water and two electrodes

with an electrical potential that detects the presence of water (one of the electrodes may be the boiler body itself).

Both controls require resetting the power supply to the control panel (after investigating the cause of the high or low level failure, especially if the first two main level controls failed to detect a low level).



Under no circumstances should the burner be kept lit if the water level is not visible (low or high), nor should water be added until the boiler has cooled down in the case of a significantly low level.

In this case, the steam valve should be closed and the boiler allowed to cool before inspection.

It is possible that the water level is "apparently" not visible because the boiler is "flooded," meaning the water level is higher than what can be seen with the visual level indicator.

In this case, the burner should also be shut off to prevent water from being drawn into the system, which could cause a water hammer effect that could damage parts of the installation.

Water hammer occurs when water enters the steam pipe and gains the velocity of the steam, potentially discharging all its dynamic energy or velocity, like a hammer blow,

when it is suddenly stopped at an elbow, valve, or other piece of steam-using equipment.

As shown in the previous diagram**: it is not advisable (and should not be) to connect automatic level controls that cut off combustion due to low water level to the boiler via pipes with shut-off valves** (only visual level gauges should have shut-off valves to isolate them from the boiler in case of glass breakage, both to prevent loss and facilitate repairs).

If there were a shut-off valve on an automatic low-level cut-off system, there would be a risk that, due to error, oversight, or malicious intent, a valve could be left closed, preventing the level control from responding and causing the boiler to run out of water, resulting in an accident due to insufficient water level in the boiler (the most common type of accident, with unpredictable consequences).

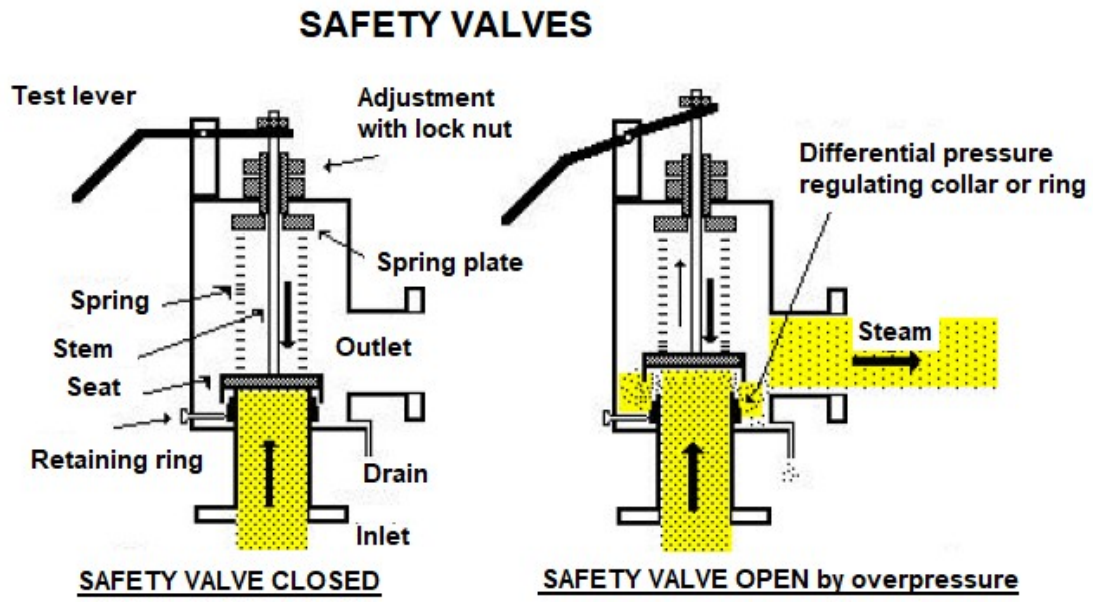
BOILER FIRE CRUSHED BY LOW WATER LEVEL

Due to a failure of the automatic level shutoff,

the burner did not turn off when the water level became low.

Often, these valves are installed under the pretext of improving level control or facilitating repairs in case of failure, but the danger far outweighs any practical benefit: **don't do it!**

It's preferable to open the level controls every few months if sludge buildup is suspected (even if they are purged every 4 hours of operation) **to clean it out** (generally, when a water softener isn't used, there's a lot of sludge in the boiler water).



Safety valves are installed at the top of the saturated steam chamber and at the superheated steam outlet.

Safety valve function is to limit the pressure inside the boiler to a maximum (this pressure is the maximum permissible working pressure, called the "ringing" pressure) by releasing excess steam to the atmosphere.

The boiler pressure can rise if the burner is not shut off in time (if it is manually operated) or if the automatic control (pressure switch) fails when the maximum (cut-off) pressure is reached.

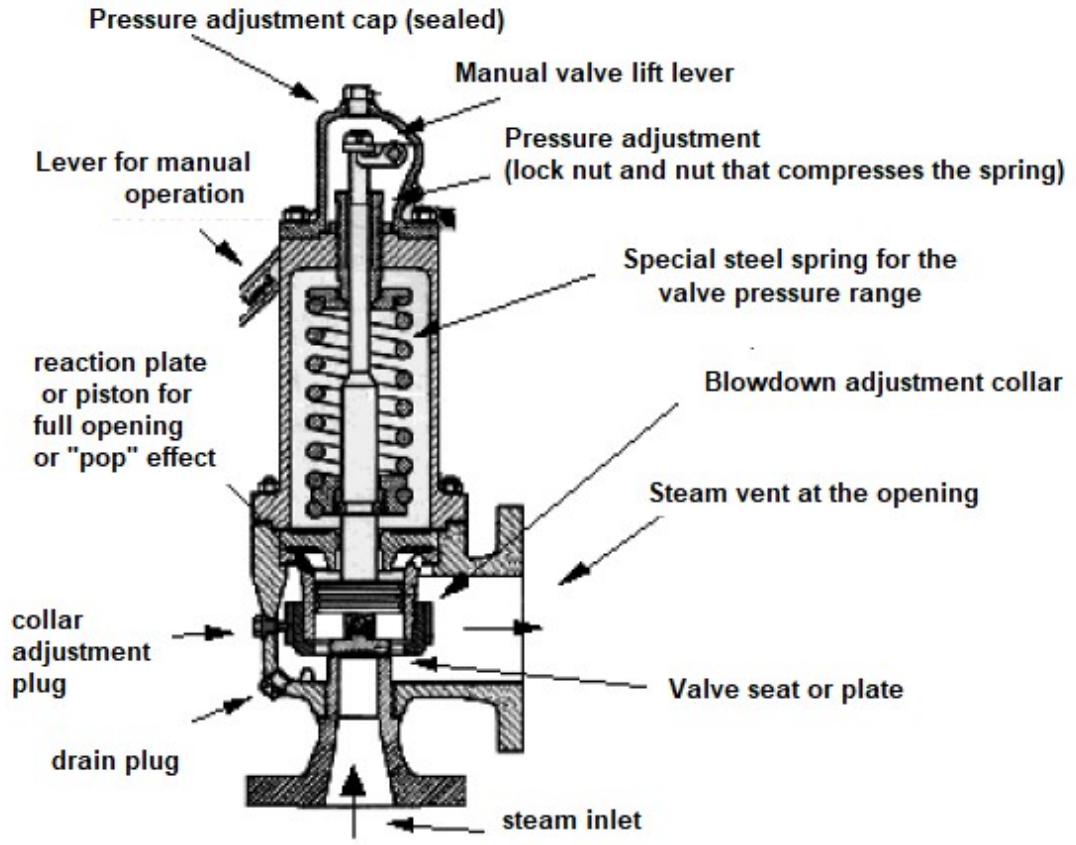
Do not confuse boiler safety valves with relief valves for steam, gases, or liquids

Boiler safety valves have notable differences:

- **They are fully opening** (or have a "pop" effect—like pulling a cork out of a bottle—necessary because the boiler generates internal pressure).

- **They have an adjustable device that allows the closing pressure to be lower than the opening pressure** (pressure differential—"blowdown"—generally adjustable with a collar on the seat).

- **They have a "lever" that allows for testing** (opening without reaching the set pressure to keep the mechanisms "free" or prevent them from seizing), by operating them periodically (weekly).


Pressure adjustment cap (sealed)
Manual valve lift lever
Pressure adjustment
(lock nut and nut that compresses the spring)
Lever for manual operation
Special steel spring for the valve pressure range
reaction plate or piston for full opening or "pop" effect
Blowdown adjustment collar
Steam vent at the opening
collar adjustment plug
Valve seat or plate
drain plug
steam inlet
BOILER SAFETY VALVE

The springs must be within the expected operating range.

The **capacity of the safety valve kg of steam/hour,** to be evacuated in case of steam overpressure in the boiler,

will be that calculated according to the standards used (no less than all the steam capable of producing the boiler under any condition, with the burner at maximum.

Generally, this capacity is achieved with two valves (except for very small boilers), or more.

To adjust the opening pressure of safety valves, they generally have a nut (with a lock nut) that adjusts a spring which pushes against the seat plate.

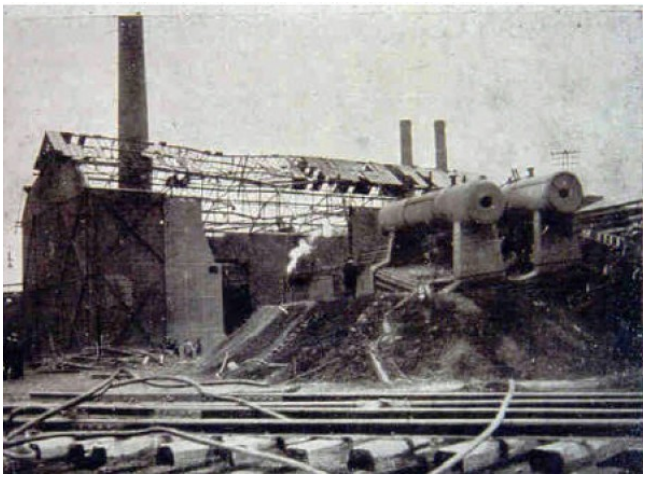
The greater the pressure on the seat, the higher the opening pressure. These valves can initially be adjusted with a hand pump for hydraulic testing, but then they must be readjusted in the boiler (since the adjustment can be affected by the temperature).

When adjusting the valves, care must be taken not to exceed the maximum allowable pressure ("ringing pressure") and not to let the pressure rise more than 6% above the maximum allowable working pressure (once the valves are open and vaporization is at its maximum).

The closing pressure is regulated according to the type of boiler and fuel (approximately 1% to 6% below the opening pressure).

The exhaust must be vented to the atmosphere through a sturdy pipe of the appropriate diameter (preferably separate from other exhausts and from itself) and in a way that prevents the steam from burning anything or anyone (the exhausts are very violent!).

Normally, a minimum of two valves are required, and they must open at different pressures (to avoid excessive decompression and often unnecessary steam loss). See below.



Never remove or operate without SAFETY VALVES: they are the only protection mechanism against steam over-pressure in the boiler in case the pressure switches or the "boilerman" fail to supervise.

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Transport of the boiler of the Minas Electric Power Plant, September 1902, URUGUAY
http://bibliotecadigital.bibna.gub.uy:8080/jspui/handle/123456789/10748